FIG. 1;

FIG. 6 is a fragmentary cross-sectional view of a second embodiment of the shaft sealing apparatus according to the present invention; and

FIG. 7 is a fragmentary cross-sectional view of a third embodiment of the shaft sealing apparatus according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Throughout the following detailed description, similar reference characters and numbers refer to similar elements in all figures of the drawings.

The first preferred embodiment of the shaft sealing apparatus according to the present invention will now be described in detail in accordance with the accompanying drawings.

Referring now to the drawings, in particular to FIGS. 1 to 5, there is shown the first preferred embodiment of the shaft sealing apparatus according to the present invention. The shaft sealing apparatus 100 is available for a vacuum processing apparatus equipped with a handling mechanism. The shaft sealing apparatus 100 comprises a vacuum casing 110 formed with a vacuum chamber 111, and a shaft housing 120 in the form of a cylindrical hollow shape and fixedly connected with the vacuum casing 110. The vacuum casing 110 has a base portion 110a formed with an opening 110b to have the vacuum chamber 111 of the vacuum casing 110 held in communication with the atmosphere 112 through the opening 110b of the vacuum casing 110. The shaft housing 120 is fixedly connected with the base portion 110a of the vacuum casing 110 by bolts 121. The shaft housing 120 has an inner cylindrical surface 120a.

The shaft sealing apparatus 100 further comprises a sleeve shaft 130 in the form of a cylindrical hollow shape and received in the shaft housing 120 to be movably supported by the shaft housing 120. The sleeve shaft 130 is held in coaxial alignment with the shaft housing 120 and rotatable around its own axis with respect to the shaft housing 120. The sleeve shaft 130 has a first axial end 130a extending in the vacuum chamber 111 of the vacuum casing 110, a second axial end, not shown, extending in the atmosphere 112, an outer cylindrical surface 130b smaller in diameter than the inner cylindrical surface 120a of the shaft housing 120, and an inner cylindrical surface 130c. The sleeve shaft 130 constitutes a driving shaft having an outer cylindrical surface and movably extending in the vacuum chamber 111 of the vacuum casing 112.

While the shaft sealing apparatus 100 has been described in the above as comprising a sleeve shaft 130 rotatable around its own axis with respect to the shaft

housing 120, the sleeve shaft 130 may be replaced by a sleeve shaft axially movable along its own axis with respect to said shaft housing 120 according to the present invention.

Though the shaft sealing apparatus 100 has been described in the above as comprising a sleeve shaft 130 in the form of a cylindrical hollow shape and received in the shaft housing 120 to be held in coaxial alignment with the shaft housing 120, the sleeve shaft 130 may be replaced by a plurality of sleeve shafts each in the form of a cylindrical hollow shape and received in the shaft housing 120 to be held in coaxial alignment with the shaft housing 120 according to the present invention.

The shaft sealing apparatus 100 further comprises a center shaft 140 in the form of a cylindrical shape and received in the sleeve shaft 130 to be movably supported by the sleeve shaft 130. The center shaft 140 is held in coaxial alignment with the sleeve shaft 130 and rotatable around its own axis with respect to the sleeve shaft 130. The center shaft 140 has a first axial end 140a extending in the vacuum chamber 111 of the vacuum casing 110, a second axial end, not shown, extending in the atmosphere 112, and an outer cylindrical surface 140b smaller in diameter than the inner cylindrical surface 130c of the sleeve shaft 130. The center shaft 140 constitutes a driving shaft having an outer cylindrical surface and movably extending in the vacuum chamber 111 of the vacuum casing 112.

While the shaft sealing apparatus 100 has been described in the above as comprising a center shaft 140 rotatable around its own axis with respect to the sleeve shaft 130, the center shaft 140 may be replaced by a center shaft axially movable along its own axis with respect to said sleeve shaft 130 according to the present invention.

The shaft sealing apparatus 100 further comprises a first sealing unit 150 provided on the first axial end 130a of the sleeve shaft 130 and held in axial alignment with the sleeve shaft 130. The first sealing unit 150 includes a retaining member 151 in the form of an annular ring shape and fixedly connected with the first axial end 130a of the sleeve shaft 130 by bolts 152, and a plurality of sealing rings 153 securely retained by the retaining member 151 of the first sealing unit 150 to be held in axial alignment with each other. Each of the sealing rings 153 of the first sealing unit 150 is in the form of an annular ring shape and intervenes between the center shaft 140 and the retaining member 151 of the first sealing unit 150 to hermetically seal the gap between the center shaft 140 and the retaining member 151 of the first sealing unit 150. The sealing rings 153 of the first sealing unit 150 are held in contact with each other.

The retaining member 151 of the first sealing unit 150 has a first axial end

151a extending in the vacuum chamber 111 of the vacuum casing 110, a second axial end 151b held in contact with the first axial end 130a of the sleeve shaft 130, an inner cylindrical surface 151c larger in diameter than the outer cylindrical surface 140b of the center shaft 140, and an outer cylindrical surface 151d. The inner cylindrical surface 151c of the retaining member 151 is formed with an annular ledge 151e connected with the first axial end 151a of the retaining member 151. The retaining member 151 of the first sealing unit 150 forms part of the sleeve shaft 130 extending in the vacuum chamber 111 of the vacuum casing 110.

Each of the sealing rings 153 of the first sealing unit 150 includes an annular resilient member 154 formed with an annular groove 154a, and an annular spring member 155 received in the annular groove 154a of the annular resilient member 154 and retained by the annular resilient member 154 as shown in FIG. 2. The annular resilient member 154 of the sealing ring 153 has a peripheral portion 154b securely retained by the annular ledge 151e of the retaining member 151, and a sealing lip 154c integrally formed with the peripheral portion 154b of the annular resilient member 154 and radially inwardly extending from the peripheral portion 154b of the annular resilient member 154 to be held in contact with the outer cylindrical surface 140b of the center shaft 140. The sealing lip 154c of the annular resilient member 154 is made of a synthetic resin constituted by an ultra high molecular weight compound.

The annular resilient member 154 of the sealing ring 153 may have a reinforcing portion 154d covered by a rubber and intervening between the peripheral portion 154b of the annular resilient member 154 and the sealing lip 154c of the annular resilient member 154 to have the resilient member 154 reinforced with the annular reinforcing portion 154d. The reinforcing portion 154d of the annular resilient member 154 is made of a metal plate in the form of an annular ring shape and is of an L-shaped cross-section taken on the plane perpendicular to the center axis passing therethrough.

The annular spring member 155 of the sealing ring 153 is operative to impart a force to the sealing lip 154c of the annular resilient member 154 to ensure that the sealing lip 154c of the annular resilient member 154 is held in tight contact with the outer cylindrical surface 140b of the center shaft 140. The annular spring member 155 of the sealing ring 153 is made of a metal wire in the form of a helical shape and is of a circular cross-section taken on the plane perpendicular to the center axis passing therethrough. The annular spring member 155 thus constructed is generally called "garter spring".

In the first embodiment of the shaft sealing apparatus according to the